Direct estimation of death attributable to smoking in Switzerland based on record linkage of routine and observational data

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Abstract: INTRODUCTION: In Switzerland, estimations of smoking-attributable deaths were based on age- and sex-adjusted hazard ratios (HRs) from foreign cohorts, precluding consideration of country-specific properties and adjustment for confounding. In order to overcome this, we analyzed recently available individual data from Switzerland. METHODS: We included 17,861 individuals aged 16 years who participated between 1977-1993 in health studies and were anonymously linked with the Swiss National Cohort. Adjusted Cox regression was used to calculate mortality HRs. Smoking status at baseline was categorized into never-smokers, former smokers, and current light or heavy smokers (<20 or 20 cigarettes/day). As covariates, we selected education, marital status, lifestyle, alcohol consumption, and body mass index. We differentiated between cardiovascular disease (CVD), cancer, and noncancer-non-CVD deaths. Smoking-attributable deaths were estimated with a HR-based approach and with age-specific prevalence rates and mortality estimates from 2007. RESULTS: Smoking men and women not only had an increased risk for all-cause (HR and 95% confidence interval vs. never-smokers: 1.71 [1.53-1.90]; 1.54 [1.36-1.75]), CVD (1.72 [1.43-2.06]; 1.50 [1.19-1.90]) and cancer (1.87 [1.56-2.25]; 1.58 [1.30-1.93]), but also for noncancer-non-CVD death (1.57 [1.29-1.89]; 1.58 [1.30-1.93]). Former smoking men had an increased risk for all-cause (1.16 [1.03-1.31]) and cancer death (1.35 [1.10-1.65]). Multivariate adjustment only slightly modified the association between smoking and mortality. Overall, 7,153 deaths per year could be attributed to smoking. CONCLUSIONS: Smoking is an important avoidable health burden in Switzerland, and its consequences may persist for decades after quitting. This stresses the need for putting more efforts in strategies aimed at preventing the onset of smoking.

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Abstract

Introduction: In Switzerland, estimations of smoking-attributable deaths were based on age and sex adjusted hazard ratios (HR) from foreign cohorts, precluding consideration of country specific properties and adjustment for confounding. In order to overcome this, we analysed recently available individual Swiss data.

Methods: We included 17,861 individuals aged ≥16 years who participated 1977-93 in health studies and were anonymously linked with the Swiss National Cohort (SNC). Adjusted Cox regression was used to calculate mortality HR. Smoking status at baseline was categorized into: never smokers, former smokers, current light/heavy smokers (< 20/≥ 20 cigarettes/day). As covariates, we selected education, marital status, lifestyle, alcohol consumption, BMI. We differentiated between cardiovascular disease (CVD), cancer, non-cancer-non-CVD deaths. Smoking-attributable deaths were estimated with a HR based approach and with age-specific prevalence rates and mortality estimates from 2007.

Results: Smoking men and women not only had an increased risk for all-cause [HR and 95% confidence interval vs. never smokers: 1.71 (1.53-1.90); 1.54 (1.36-1.75)], CVD [(1.72 (1.43-2.06); 1.50 (1.19-1.90)] and cancer [(1.87 (1.56-2.25); 1.58 (1.30-1.93)], but also for non-cancer-non-CVD death [(1.57 (1.29-1.89); 1.58 (1.30-1.93)]. Former smoking men, had an increased risk for all-cause [1.16 (1.03-1.31)] and cancer death [1.35 (1.10-1.65)]. Multivariate adjustment only slightly modified the association between smoking and mortality. Overall, 7,153 deaths per year could be attributed to smoking.

Conclusions: Smoking is an important avoidable health burden in Switzerland and its consequences may persist for decades after quitting. This stresses the need for putting more efforts in strategies aimed at preventing the onset of smoking.

Introduction

Smoking increases the risk of dying from cancer, cardiovascular diseases (CVD) and other causes (Gu et al., 2009; Katanoda et al., 2008; Rostron, 2011; Sasco, Secretan, & Straif, 2004; White, 2007). According to the WHO, tobacco consumption is responsible for approximately 6 million deaths annually worldwide and is thus one of the most important avoidable causes of premature death (World Health Organization, 2011). Available estimations for Switzerland proceed on the assumption of 9,000 smoking-attributable deaths (6,427 men and 2,774 women in 2007); this amounts to 15% of all deaths in Switzerland (Federal Statistical Office, 2009). These figures are based on the Smoking-Attributable Mortality, Morbidity and Economic Cost (SAMMEC) method (Centers for Disease Control and Prevention, 2004), which was developed by the US Centers for Disease Control and Prevention (CDC) and which is based on the relative risks of death of American Cancer Prevention Study II (1982 – 1988) participants (Thun et al., 1997). Moreover, data from the Swiss Health Survey (smoking prevalence) and the Causes of Death Statistics of the Swiss Federal Statistical Office (SFSO) were used. In these estimations, the relative risks associated with smoking have been adjusted for age effects, but not for potential confounders such as a low level of education, alcohol consumption or obesity (Faeh, Braun, Tarnutzer, & Bopp, 2011; Hart, Davey Smith, Gruer, & Watt, 2010; Rostron, 2011; Thun, 2000). Moreover, the application of relative risks of death from older and/or foreign studies to the Swiss population could generate erroneous results. Since Switzerland lacks of a nationally representative general cohort, to date, figures on multivariable adjusted relative risks associated with smoking are not available. The latter are a prerequisite for accurate assesment of the number of smoking-attributable deaths. In Switzerland, between 1975 and 1987, smoking prevalence declined in men from 50% to 38% and in women from 29% to 25% (Fahrenkrug & Mueller, 1987). Between 1992 and 2007, smoking prevalence only decreased slightly from 37% to 32% in men and stagnated in women (24%) (Bundesamt für Statistik, 2010). A public smoking ban became effective nationwide in 2010. Cigarette costs are comparably low, and there is relatively little restriction of access.

We aimed at specifying the risk and burden of death associated with smoking in Switzerland on a population level. Our study is based on an anonymous record linkage that combined baseline data from health studies conducted in Switzerland between 1977 and 1993 with individual data from national censuses, mortality and emigration records up to the end of 2008. The large number of clinical and lifestyle variables, the long

follow-up period and the quality of exposure and outcome data allows validation of existing estimations of the health burden due to smoking in Switzerland for the first time.

Methods

Study population

We used pooled data from two cross-sectional studies conducted in Switzerland between 1977 and 1993: (1) the National Research Programm 1A (NRP 1A) (Gutzwiller, Nater, & Martin, 1985) and (2) the Swiss MONICA (MONItoring of trends and determinants in CArdiovscular disease) study, which was conducted in three waves (data collection phases) (Wietlisbach, Paccaud, Rickenbach, & Gutzwiller, 1997). In both studies, no provision was made for a mortality follow-up. This shortcoming could be overcome by an anonymous record linkage with the Swiss National Cohort (SNC) (Bopp et al., 2009). The characteristics of the two studies are summarized in Table 1. The study population comprises 17,861 participants of whom 3,953 died during the follow-up period of up to 35 years (mean: 21.4 years; for more details, see Table 2 in the result section).

Record linkage procedure

In order to determine vital status of MONICA and NRP 1A participants, anonymous record linkage with the SNC was used. The SNC encompasses all residents of Switzerland included in the national censuses of 1990 and 2000 (6.8 and 7.3 million, respectively). As described elsewhere, deterministic and probabilistic methods were used to link anonymised census, death and emigration records (Bopp et al., 2009). In a second phase, SNC information was separately linked to MONICA and NRP 1A data, respectively. This additional record linkage was also entirely anonymous. The linkage was based on procedures including all potential identification variables, i.e. variables available in the two cross-sectional studies and in the SNC. The minimal required information for a promising record linkage was sex, exact date of birth and place of residence (community). Additional identification variables were nationality, marital status, educational category and profession (Bopp, Braun, Faeh, & Gutzwiller, 2010; Bopp, Braun, Gutzwiller, & Faeh, 2012). In a last step, the separately linked MONICA and NRP 1A datasets were pooled, providing a combined dataset, which comprised all variables available in both studies.

Smoking status

In all studies, smoking habits were asked very similarly (for exact wording see online supplementary material). Smoking status was categorized as follows: never smokers, former smokers, current light smokers (< 20 cigarettes/day), current heavy smokers (≥ 20 cigarettes/day).

Covariates

The following covariates were considered: age, sex, survey (wave: NRP 1A; MONICA I, II, III), area (town or canton of residence), nationality, educational level (mandatory/secondary, upper secondary and tertiary), marital status (never married, married, widowed, divorced), body mass index (BMI, calculated from measured height and weight), blood pressure (systolic and diastolic), total blood cholesterol. As proxies for a healthy lifestyle, frequency of sport (every day, several times per week, once per week, less frequent, never) and healthy eating (three main meals per day, yes or no) were used. Information on alcohol consumption was only available as binary variable from a questionnaire about the subjects' alcohol consumption on the previous day (yes or no). From these variables we selected variables for inclusion in our models as explained below.

Outcome variables

Causes of death were classified according to ICD (International Classification of Diseases) revisions 8 (ICD-8) and 10 (ICD-10). In Switzerland ICD-8 was used until 1994, followed by ICD-10 thereafter. Due to the relatively small number of some cause specific deaths, causes of death had to be grouped into CVD (ICD-8: 390–458; ICD-10: I00–I99), cancer (ICD-8: 140–239; ICD-10: C00–C99; D00–D48), and non-cancer-non-CVD (remainder).

Statistical analyses

For descriptive analyses, we calculated counts, means and proportions of the variables of interest. Mortality rates by sex were age-standardized with the direct method to the WHO's "European" standard age structure (Day, 1982). Cox proportional hazards regression models were used to calculate hazard ratios (HRs), 95% confidence intervals (CIs) and p-values. We calculated different Cox models to assess the influence of smoking on survival adjusted for an increasing number of covariates. All models were calculated separately for men and women. In Model 1 (basic model), we adjusted for age and survey (wave): NRP 1A, MONICA I, II, III; in Model 2, additionally for educational level and marital status; in Model 3, additionally for three

main meals per day, sport and alcohol consumption; in Model 4, additionally for body mass index; in Model 5, additionally for systolic blood pressure and total blood cholesterol (CVD mortality only). Model choice was based on Akaike's information criterion (AIC) and Bayesian information criterion (BIC). To avoid over adjustment, the inclusion of the variables blood pressure and cholesterol level was dispensed with in further calculations because these two variables are intermediate variables on the leading pathway between smoking and death. The categorical variable 'survey (wave)' was used in all models in order to control for possible cohort and period effects. For the continuous variables age and BMI models with quadratic terms were tested.

To examine the dose-response relationship between smoking and mortality, current smokers were divided into two groups according to the number of cigarettes smoked per day (current light smokers < 20 cigarettes/day, current heavy smokers ≥ 20 cigarettes/day). Separate analyses with 'number of cigarettes smoked per day' as a continuous variable were also performed. To investigate the benefits of cessation separate analyses of former smokers (age at quitting < 40 years and ≥ 40 years, respectively) were performed.

In order to test for potential confounding, sensitivity analyses were conducted by additionally adjusting for nationality and area. In order to analyse the impact of duration of follow-up period, we also conducted separate analyses terminating the follow-up period after 10, 15, 20, 25, and 30 years.

The population attributable risk (PAR) was estimated for all causes of death by sex (x), age group (16-64 years, 65-92 years) (a) and smoking status (former, current) (s) using the following equation, in which P denotes the smoking prevalence, and RR the relative risk (compared with never smokers):

$$PAR_{x,a,s} = (P_{x,a,s} \times [RR_{x,a,s} - 1]) \div (P_{x,a,s} \times [RR_{x,a,s} - 1] + 1)$$

We substituted the RRs in the equation by the HRs estimated from the basic model (Model 1) and from the adjusted model (Model 4) (partially adjusted PAR).

To estimate the number of smoking-attributable deaths (SAD) the following equation was used:

$$SAD_{x,a,s} = PAR_{x,a,s} \times \text{Number of deaths}_{x,a}$$

The total SAD was calculated as the sum of the estimates by sex, age group and smoking status.

Age-specific prevalence data of the Swiss Health Survey 2007 (Bundesamt für Statistik, 2010) was used. The SAD was estimated using data from the Swiss Cause of Death Statistics 2007 (Bundesamt für Statistik, 2012). Analyses were performed with STATA 11 (StataCorp, Texas, USA, 2009).

Results

In Table 2 the characteristics of the study population with regard to sex and smoking status are compiled. In all, 26.4% of the women and 40.5% of the men smoked. Heavy smokers got less exercise, ate less healthily, and drank alcoholic beverages more frequently than never smokers. Altogether, female heavy smokers were less frequently obese and had high blood pressure less often than female never smokers. Male heavy smokers had a slightly higher cholesterol level than never smokers.

Figure 1 shows all-cause and cause specific mortality risks (HRs) according to smoking status and sex. The association between smoking and mortality was adjusted in four models with an increasing number of variables. In Figure 1 the HRs for the basic model (Model 1) and the fully adjusted model (Model 4) are specified. Detailed information on all models is given in Table S1 (online supplementary material).

In men and women, all-cause, CVD, and cancer mortality risks were significantly elevated in smokers compared with never-smokers in all models (except CVD mortality in female light smokers). Heavy smokers exhibited significantly higher HRs than light smokers (except cancer mortality in women). This dose-response relationship was confirmed in an analysis of the HRs with smoking as a continuous variable. With each additional daily smoked cigarette the mortality risk increases by approximately 3% (for details, see Table S2, online supplementary material). The all-cause and cancer mortality risks in male former smokers were significantly elevated compared to never smokers; in female former smokers none of these associations reached a significant level. The elevated cancer mortality in former smokers was primarily due to lung cancer, which comprised 24.8% of all cancer deaths in male former smokers in our analysis (female former smokers: 4.4%). The HR of male former smokers with reference to lung cancer mortality was 2.12 (CI 1.26-3.51). Men who had stopped smoking at ages < 40 years showed no increased mortality risk compared to never smokers; men who stopped smoking at later ages had a significantly higher all-cause and cancer mortality risk [HR and CI: 1.24 (1.08-1.41); 1.46 (1.17-1.83)]. However, the HRs of the two age at quitting groups did not differ significantly. In women none of these associations reached a significant level (for details, see Table S3, online supplementary material).

With regard to CVD mortality, separate analyses were additionally adjusted for cholesterol level and systolic blood pressure. This resulted in a slight reduction in the association between smoking and CVD mortality in men; in women, in a slight amplification (for details, see Table S1, online supplementary material).

With reference to all-cause mortality, there were no significant differences in the HRs by smoking status between the analysed age groups (16-59 years and 60-92 years, respectively). However, in former smokers the age group of the 60-to-92-year old subjects differed only significantly in Model 2 (for details, see Table S4, online supplementary material).

Sensitivity analyses using the additional variables nationality and area in the completely adjusted model, as well as with different follow-up periods revealed no noteworthy differences in the relative risks of death (see Table S5, online supplementary material). With reference to all-cause mortality, there were no significant differences in the HRs by smoking status between the survey waves (NRP 1A, MONICA I, II, III). However, in male former smokers only the MONICA I and II participants differed significantly from never smokers and in female former smokers the MONICA III participants showed also a significantly elevated risk compared to never smokers. Moreover, the all-cause mortality risks of participants of MONICA II and III were significantly lower compared to NRP 1A (for details, see Table S6, online supplementary material). An analysis of the non-cancer-non-CVD mortality excluding accident deaths showed that the differences were not significant compared to the results based on non-cancer-non-CVD deaths including accidents.

The increasing adjustment in the models resulted in only relatively small attenuations in the HRs, whereby the strongest effects were revealed in the heavy smokers and differed according to sex. In male heavy smokers the fully adjusted model resulted in a slight reduction in the HR for all causes of death compared to the basic model. In contrast to this, the HR for CVD mortality in female heavy smokers increased slightly compared to the basic model.

Figure 2 shows the estimated SADs for all-cause mortality for the year 2007 according to sex, age group and smoking status. Overall, 7,153 deaths (5,363 in men and 1,790 in women) were attributable to smoking using the basic Cox model (11.8% of all deaths) and 7,392 deaths (5,252 in men and 2,140 in women) using the adjusted Cox model (12.2%). The changes resulting from consideration of the different covariates in the Cox-model differs by sex: In men, the SAD decreased by 2.0% after adjustment; in women, the value

increased by 19.6%, due to an increase in the age group of 65-92 years (detailed information is given in Table S7, online supplementary material).

Discussion

Main results

To date, estimation of deaths attributable to smoking in Switzerland was based on relative risks of death obtained from foreign popualtions (USA) that were only adjusted for age and sex. Thanks to anonymous record linkage of routine and observational data, in Switzerland, it is now for the first time possible to use country-specific relative risks, to consider the mutual impact with other risk factors and to account for possible confounding, finally allowing to validate these figures. In the investigated study population, smoking in women and men was not only, as expected, associated with an elevated risk for all-cause, cancer and CVD death, but also for non-cancer-non-CVD death. In men, the risk for all-cause and cancer mortality was significantly elevated in former smokers compared to never smokers. This was also true after full adjustment and consideration of the full follow-up period. Even when considering all covariates, the association between smoking and death changed only slightly. Altogether, 18.3% and 5.7% of deaths in men and women, respectively, could be attributed to smoking. In Switzerland this amounted to a total of 7,153 smoking-attributable deaths in 2007.

Current smokers

The lack of sex differences in HR for all-cause, CVD and cancer mortality has been repeatedly shown (Gellert, Schottker, & Brenner, 2012; Jamrozik et al., 2011; Liaw & Chen, 1998; Murakami et al., 2011; Rostron, 2011). In contrast, in a study from Japan, the HR for CVD death was significantly higher in female than in male smokers; the opposite was the case for cancer (Katanoda et al., 2008). Similar to younger individuals, smoking was also associated with all-cause mortality in those older than 60 years of age; this agrees with the result of a recently published meta-analysis of 17 cohort studies (Gellert et al., 2012). In their study, which was based on the American Cancer Prevention Study II, Thun et al. found significantly lower HRs in the age group ≥ 65 years for specific causes of death, such as ischemic heart diseases and stroke, compared to the age group 35 to 64-years (Thun, 2000). In our population, there was no significant difference between the age groups in the relative CVD-risk associated with smoking.

Former smokers

The elevated relative risk of all-cause death observed in male former smokers agrees with the results of studies from Japan and the USA (Katanoda et al., 2008; Rostron, 2011). Gellert et al. also obtained the same result in their meta-analysis of the age group ≥ 60 years (Gellert et al., 2012). In contrast to our results, these studies also found the same association for female former smokers and in the study from Japan, also for CVD mortality in addition to cancer mortality. However, the follow-up periods in these studies were in some cases substantially shorter than in our analysis. Conversly, in the Seven Countries Study, which had a comparable follow-up period of 25 years, no elevated risk for all-cause, cancer and CVD death could be found in former smokers (Jacobs et al., 1999).

The fact that, in male former smokers, only the risk of cancer but not of CVD death was increased in our analysis can be explained by the finding that after quitting smoking the relative risk of death for CVD decreases more rapidly than for lung cancer (Oza, Thun, Henley, Lopez, & Ezzati, 2011), which is decisively responsible for the elevated risk of cancer death in male former smokers. The fact that the risk in female former smokers was not elevated as well could be due to presumably lower exposure in female than in male former smokers. This assumption is supported by the circumstance that the average number of cigarettes smoked daily was lower in women than in men (see Table 2). Moreover, the average age of quitting was significantly lower in female former smokers (35.4 years) than in male former smokers (39.0 years).

The association between age at quitting and mortality risk, recently shown by Pirie, Peto, Reeves, Green & Beral (2012) could only partially be replicated with our data. However, due to the relatively small numbers of former smokers especially in women, our estimates were relatively imprecise.

Deaths attributable to smoking

The PAR for men and women in the basic model (18.3% and 5.7%) or in the adjusted model (17.9% and 6.8%) were somewhat lower than that estimated by the SFSO (21.8% and 8.8%) (Federal Statistical Office, 2009). Accordingly, the absolute number of smoking-attributable deaths in the year 2007 was lower than the SFSO estimate of 6,427 for men and 2,774 for women. However, these numbers are only comparable to a limited extent because the SFSO calculations are based on 22 selected smoking-attributable causes of death, whereas in our analysis all causes of death were considered. Moreover, the SFSO used relative risks of death

of American Cancer Prevention Study II (1982–1988) participants, which tend to be higher than our risk estimates.

The smoking-attributable deaths were calculated analogously to the prevalence-based SAMMEC method, which was developed by CDC (Centers for Disease Control and Prevention, 2004). The indirect estimates of smoking-attributable deaths according to Peto, Lopez, Boreham, Thun, & Heath (1992), which rely on the assumption of lung cancer as the risk model rather than on the prevalence of smoking obtained from population studies, generated lower numbers for 2007 in Switzerland for men (16%), and somewhat higher for women (8%) (Peto, Lopez, Boreham & Thun, 2012b). For developed countries, Peto et al. obtained 21% for men and 8% for women in 2005 with their indirect estimate (Peto, Lopez, Boreham & Thun, 2012a).

Adjustment

The increasing adjustment with covariates resulted in relatively small alterations in the association between smoking and mortality. This is coherent with studies from the USA (Malarcher et al., 2000; Rostron, 2011; Thun, 2000). A reduction in the number of smoking-attributable deaths (all-cause mortality) in men subsequent to full adjustment and an increase in women were also observed in a US-study (Rostron, 2011).

Limitations

The participants in the MONICA Study exhibit a lower mortality, particularly with regard to CVD, than the Swiss general population and are probably healthier than the latter (Bopp et al., 2010). Since MONICA and NRP 1A are similar in design, it can also be assumed that the participants in the NRP 1A were healthier than the general population.

Because only the baseline measurement was available for the smoking status and the covariates, changes in the smoking status and in the covariates in the course of the follow-up could not be considered. Therefore, one must assume that the present estimate of the association between smoking and mortality is a conservative one and that the effect was underestimated because it tends to "dilute" over time (Faeh et al., 2011). Also, it must be assumed that the shift from smoker to former smoker occurs more frequently than the shift from non-smoker to smoker (Kawado et al., 2005). This would also explain the slightly decreasing HRs with increasing follow-up time in male current light smokers (see Table S5, online supplementary material).

The participants of the two studies belong to different periods of time and have a different length of follow up. However, our analyses by survey wave and with differing follow-up periods exhibited no significant differences in the relative risk for all-cause death by smoking status and sex (see Table S5 and S6, online supplementary material). Moreover, the categorical variable 'survey (wave)' was used in all models to control for possible cohort and period effects.

The dose-response relationship between smoking and mortality was only coarsely analysed in two categories on the basis of the number of cigarettes smoked per day because too many values were lacking for the 'age of smoking start' variable and thus no "pack years" could be calculated. But even this coarse analysis clearly revealed the dose dependence. No information on the quantity of previously smoked cigarettes was available for the former smokers; therefore, no differentiation could be made for the degree of exposure in this category.

Assessment of healthy lifestyle was restricted to coarse proxies (frequency of sport and three main meals per day). Only rough information on alcohol consumption was available from a questionnaire (subjects' alcohol consumption on the previous day). Exact information on the amount of alcohol consumed was only available for NRP 1A. A separate analysis of the NRP 1A data with alcohol in grams consumed per day showed that the dichotomous variable which we used with the pooled data set represents a good approximation of average alcohol consumption.

SADs were estimated using smoking prevalence and number of deaths for the year 2007. However, most smoking-attributable deaths are the result of smoking in previous decades. Overall, in Switzerland smoking prevalence declined since 1975. Therefore, it must be assumed that our SADs were somewhat underestimated. Due to the relatively small number of deaths, we could only estimate age-specific SADs for all-cause mortality. Since we used unadjusted (basic Cox-model) or only partially adjusted (adjusted Cox-Model) PARs, our estimation does not fully account for confounding.

Conclusions and public health implications

Responsible for 12% of all deaths, smoking is still one of the most important avoidable risk factors for premature death in Switzerland. Our results also confirm the increased risk of death from CVD, cancer and other causes – which has been observed in many studies – for Switzerland. Multivariate adjustment had only relatively small effects on this association. This means that estimates of smoking-attributable deaths which

are only adjusted for age, such as those published by the SFSO, are not substantially distorted by sociodemographic variables, clinical or life style factors that are associated with smoking. Our results also demonstrate that the consequences of smoking are very long-term, as shown by the fact that we were able to observe an elevated risk of death in male former smokers for a mean follow-up period of 21.4 years. Even if all smokers quitted smoking today, the effects of smoking on the mortality would still be noticeable for decades. Therefore, it is important to undertake greater efforts to prevent people from starting to smoke. This includes not only the recently implemented public smoking ban in restaurants, but also increasing the tobacco prices, restriction of access to tobacco products, prevention of advertising in all media (particularly that oriented toward youth) , and increasing the minimum age from which consumption of cigarettes is permitted.

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Declaration of Interests

None.

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Tables and figures

Table 1 Characteristics of included health studies and participants

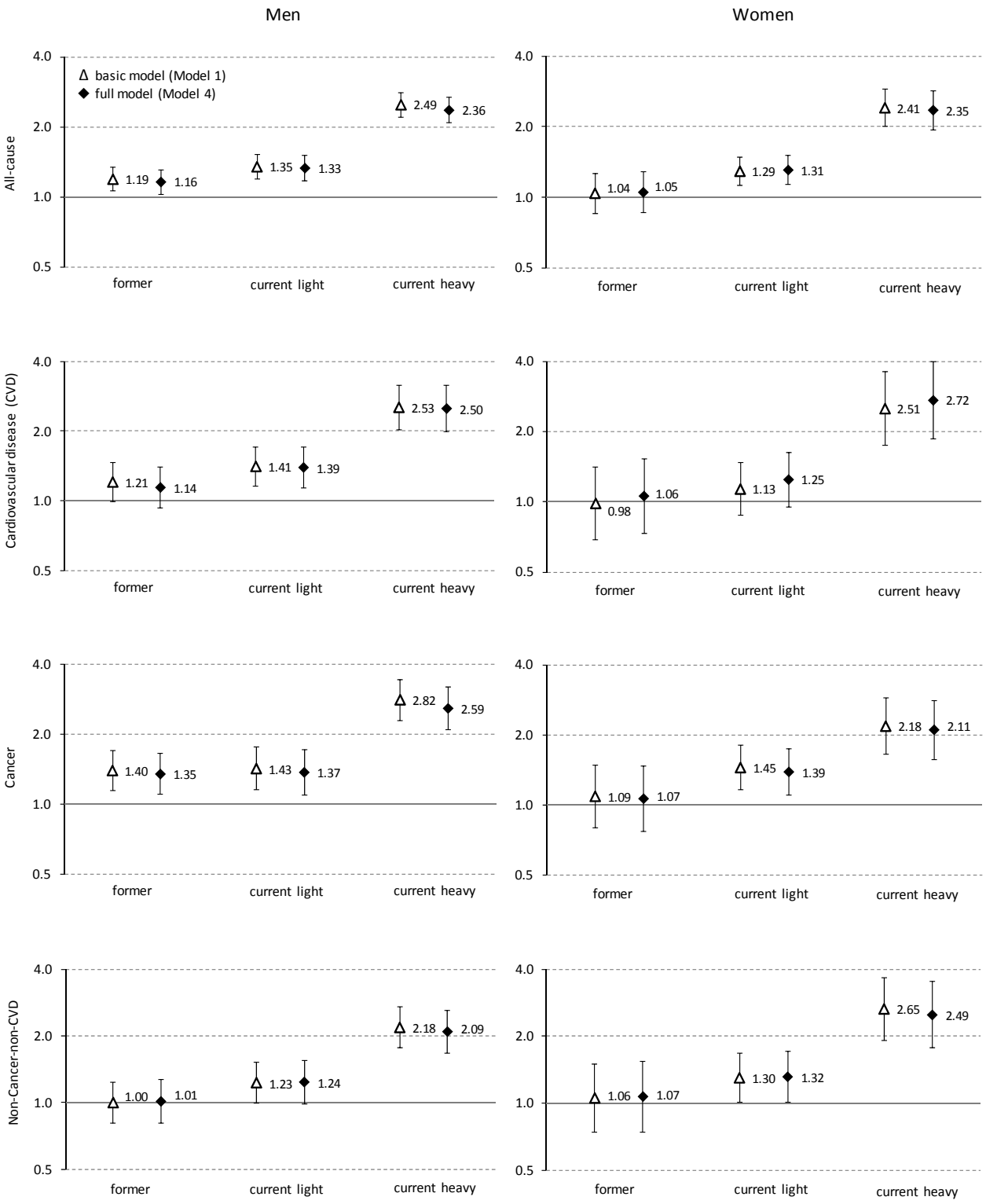
	National Research Program 1A (NRP 1A) (Gutzwiller et al., 1985)	Swiss MONICA* Study (Wietlisbach et al., 1997)
Study	Community health promotion initiative focused on cardiovascular disease prevention	Swiss part of MONICA, an international multicentre project of the WHO (Bothig, 1989)
Study design	Cross-sectional	Cross-sectional
Area of Switzerland	Five towns: Aarau, Lugano, Nyon, Solothurn, Vevey	Three cantons: Vaud, Fribourg, Ticino
Baseline year	1977–1979	MONICA I: 1984–1986 MONICA II: 1988–1989 MONICA III: 1992–1993
Sampling procedure	Random sample of individuals aged 16–69 years (4,386 persons), additional 4,245 individuals aged ≥ 16 years participated spontaneously	Random sample of individuals aged 25–74 years
Data collection (baseline)	Study participants attended a health examination and completed a self-administered questionnaire	Study participants attended a health examination and completed a self-administered questionnaire
Participation rate	65% (Swiss nationals) and 42% (foreign nationals) (Gutzwiller, Junod, Epstein, Jeanneret, & Schweizer, 1980)	Vaud/Fribourg: - MONICA I: 60% - MONICA II: 63% - MONICA III: 54% Ticino: - MONICA I: 78% - MONICA II: 74% - MONICA III: 76% (Bopp et al., 2010)
Eligible participants	8,539	10,160
Linkage success	93.8% of eligible participants could be linked to a census, mortality and/or emigration record (Bopp et al., 2012)	97.0% of eligible MONICA participants could be linked to a census, mortality and/or emigration record (Bopp et al., 2010)
End of follow up (censoring time point)	12/31/2008	12/31/2008
Participants for survival analysis (n)	8,008	9,853
Mean follow up time (years)	25.8	17.9
Women (%)	53.9	49.6
Swiss Nationality (%)	80.2	81.9
Mean age (years)	42.8	47.2
Smoking prevalence (%)	38.7	28.7
Men		
Former smokers	18.8	27.4
Current smokers	50.7	32.9
Women		
Former smokers	7.5	11.9
Current smokers	28.4	24.4
Deaths (n)	2,427	1,526

*MONICA: MONItoring of trends and determinants in CArdiovscular disease

Table 2 Characteristics of the study population, by smoking status and sex

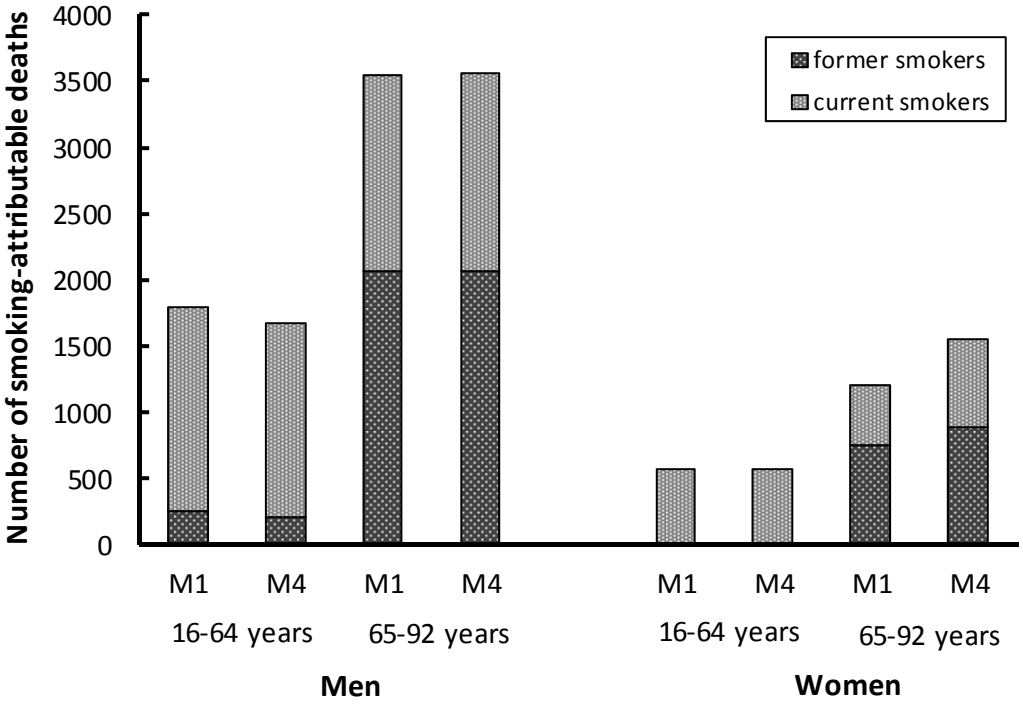
	Men				Women			
	Never smokers	**Former smokers**	**Current light smokers**	**Current heavy smokers**	**Never smokers**	**Former smokers**	**Current light smokers**	**Current heavy smokers**
Participants (n)	3,096	2,051	1,708	1,798	5,857	903	1,574	839
Participants (in % of total n, by sex)	35.8	23.7	19.7	20.8	63.9	9.8	17.2	9.2
Mean age (years)	44.6	48.5	44.0	42.4	47.9	43.2	40.5	40.1
Mean follow-up time (years)	20.8	19.9	22.5	19.7	21.9	21.6	23.6	21.5
Mean number of cigarettes smoked per day	–	–	9.5	27.0	–	–	9.2	24.2
Mortality								
All cause								
Deaths (n)	610	542	525	499	1,272	112	244	139
Person-years (py)	64,278	40,836	38,452	35,388	128,461	19,486	37,106	18,012
Age standardized rate (per 100,000 py)	655	760	860	1,390	421	437	538	934
Cardiovascular disease (CVD)								
Deaths (n)	217	191	203	139	498	33	66	33
Deaths (in % of all-cause deaths)	35.6	35.2	38.7	27.9	39.2	29.5	27.0	23.7
Age standardized rate (per 100,000 py)	233	263	317	392	153	129	150	329
Cancer								
Deaths (n)	198	206	165	200	395	45	103	61
Deaths (in % of all-cause deaths)	32.5	38.0	31.4	40.1	31.1	40.2	42.2	43.9
Age standardized rate (per 100,000 py)	191	285	256	453	146	148	209	315
Covariates								
Education								
Tertiary (%)	24.9	23.0	20.2	16.8	12.6	19.8	14.3	13.0
Upper secondary (%)	48.7	51.6	46.2	54.3	42.6	49.2	47.9	48.3
Mandatory and secondary (%)	26.4	25.4	33.6	28.9	44.9	30.9	37.8	38.6
Marital status								
Never married (%)	19.9	8.6	19.4	16.6	14.8	12.1	22.2	18.3
Married (%)	75.2	85.8	74.6	74.7	71.5	75.3	65.6	63.4
Widowed (%)	1.3	1.2	1.8	1.1	8.9	4.9	4.9	4.4
Divorced (%)	3.6	4.4	4.2	7.6	4.8	7.8	7.3	14.0
Sport								
Every day (%)	5.0	5.4	6.8	3.2	7.0	7.2	5.7	3.0
Several times per week (%)	23.2	20.5	18.0	13.7	11.9	19.2	14.9	11.0
Once per week (%)	23.1	19.6	22.5	16.3	23.4	26.3	24.3	18.7
Less frequent (%)	19.0	18.7	14.5	21.5	12.7	16.3	13.8	15.9
Never (%)	29.7	35.7	38.2	45.4	44.9	31.0	41.4	51.3
Three main meals per day (%)	71.0	66.9	69.2	48.1	80.0	74.6	66.0	46.5
Alcohol consumption, previous day (%)	64.1	74.7	74.2	79.0	35.7	42.2	48.5	49.5
Body mass index (kg/m^2)								
Mean (kg/m^2)	25.5	26.5	25.1	25.4	24.6	23.8	23.2	23.2
Overweight: BMI 25–29.9 (%)	42.3	50.4	40.1	42.9	28.5	23.9	20.0	19.0
Obesity: BMI ≥ 30 (%)	10.7	15.6	9.0	8.8	11.3	7.3	6.2	6.0
Blood pressure (mmHg)								
Mean systolic (mmHg)	130.8	133.6	130.2	130.5	127.8	121.4	121.2	121.5
Mean diastolic (mmHg)	81.0	82.2	80.0	79.7	78.0	75.6	74.8	75.3
≥ 140 or ≥ 90 mmHg (%)	30.3	37.8	28.6	29.5	26.2	15.6	14.4	13.8
Total cholesterol (mmol/l)								
Mean (mmol/l)	6.0	6.2	6.0	6.2	6.0	5.9	5.9	6.0
≥ 6.5 mmol/l (%)	29.1	36.8	24.3	35.0	29.5	25.0	24.3	27.6

Current light smokers: < 20 cigarettes/day, current heavy smokers: ≥ 20 cigarettes/day
Population sample: 8,665 male participants and 9,196 female participants of NRP 1A, 1977–79 and Swiss MONICA study, 1983–92, 16–92 years at baseline



Model 1: adjusted for age and survey wave
Model 4: additionally adjusted for education, marital status, three main meals per day, sport, alcohol consumption and BMI
Current light smokers: < 20 cigarettes/day, current heavy smokers: ≥ 20 cigarettes/day
Population sample: 8,665 male participants and 9,196 female participants of NRP 1A, 1977–79 and Swiss MONICA study, 1983–92, 16–92 years at baseline

Figure 1 Adjusted hazard ratios (with 95% confidence intervals) for mortality by cause of death, sex and smoking status (reference: never smokers)



M1: basic model, adjusted for age and survey wave
M4: full model, additionally adjusted for education, marital status, three main meals per day, sport, alcohol consumption and BMI
Population sample: 8,665 male participants and 9,196 female participants of NRP 1A, 1977–79 and Swiss MONICA study, 1983–92, 16–92 years at baseline

Figure 2 Absolute numbers of smoking-attributable deaths for all-cause mortality for the year 2007 by sex, age group and smoking status